Motion properties of satellites around external spiral galaxies

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ABSTRACT

We are analyzing a sample of closeby galaxy systems, each comprising a bright isolated spiral and its satellites. We find an excess (56%) of prograde satellites over retrograde, which basically holds for all angular displacements from the primary major axis. Monte Carlo simulations show that interlopers and mixing systems at different distances in the sample should not affect porcentages sensibly.

1. Introduction

The currently accepted theories of galaxy formation rest on the basic idea that large objects are formed by aggregation of low mass elements. In this scenario, systems such as a massive primary with its satellite galaxies are ideal gravitationally bound environments where to investigate the mechanisms which control mass aggregation in the Universe.

Due to the limited number of satellites per system (Zaritsky et al. 1997, McKay et al. 2002, Prada et al. 2003), a statistical approach is used here, following the method of Zaritsky (Zaritsky et al. 1993): providing that the primaries are selected in a consistent way, all the satellites are considered as part of the same system, thus orbiting the same fictitious primary. We selected a suitable sample of large isolated primary spirals with their satellites, using data from the Sloan Digital Sky Survey (SDSS) Early Data Release and Data Release 1. The selection follows the criteria reported by Prada (Prada et al. 2003).

Here we show the preliminary results on the prograde/retrograde ratio in our sample. We also compare our results with those obtained by Zaritsky (Zaritsky et al. 1993, 1997), who uses a sample of 57 primaries with measured rotation direction and 95 satellites. Through this contribution we call this sample "ZS". ZS primaries velocity upper limit is 7000 km/s.

2. The data

The kinematics data on the selected sample come both from the SDSS and from our observations. We took receding velocities, absolute magnitudes and positions for primaries and satellites from the SDSS database; the morphological types of the primaries have been taken from the Leda database and carefully checked visually from the SDSS images, or devised visually when not available in the literature.

Our sample includes 141 spirals with 200 satellites; the primaries have been selected by absolute brightness M_B to lay in the magnitude bin [-20.5 -19.5], and below 11000 km/s in recessional velocity. This velocity limit was chosen because, as by definition satellites are at least two magnitudes fainter than their primaries, the satellites of our faintest primaries will never be brighter than $M_B = -17.5$. Given the apparent B magnitude limit of SDSS (about 18.5, see Stoughton et al. 2002), $M_B = -17.5$ is reached at 11000 km/s (h = 0.7).

Through an ongoing observational programme, we are measuring the rotation direction of the primaries of the sample. We measured the Sky Position Angle of the primaries from the SDSS images and aligned the slit along the major axes.

The side-to-side Doppler shift was measured using the Hα emission line around 6650 $\AA$, and comparing it with sky lines. Our doppler shift detection has always been better than 10 σ. Some of the galaxies show no detectable Hα emission, while for one object we could recover the rotation curve from the literature (ngc2841, Afanasiev & Silchenko 1999), yelding a sample of 41 primaries with a satellite population of 64 objects in total. If we want to make comparisons with ZS, then we must match its velocity limit of 7000 km/s, and then we are left with 23 primaries and 36 satellites.

Observations were carried out using the William Herschel (4.2 m) and Isaac Newton (2.5 m) telescopes at ING (La Palma), with the intermediate dispersion spectrographs ISIS and IDS.

We performed a statistical analysis on the observed part of the sample, which is shown in Figure 1 *a* and *b*, and a preliminary comparison with ZS.

For the statistical analysis, three ranges of angular separation from the primary major axis are considered: $\pm 30°$, $\pm 45°$, $\pm 45°$, plus the total of each subsample ($\pm 90°$). The choice of selecting satellites by their angular displacement from the primary major axis was made to correlate the satellite motions directly with the angular momentum of the primary.

3. Conclusions

Using the whole sample, we find around 56% of prograde satellites at all angular distances from the primary major axis. In the case of $v < 7000$ km/s, we find a slightly higher

porcentage (58%) (Figure 1a), while the ZS yelds 51% over the total set and 50% at small angular distances from the primary major axis.
We find that the mean velocities of retrograde satellites are nearly always much

larger than those of prograde, while the mean distances are usually comparable.
We also show a histogram of the distribution of prograde/retrograde velocities in our sample (Figure 1b), where it can be seen that the peak count is on the prograde side, but very close to zero velocity.
Through Monte Carlo simulations, we estimated that the contamination of interlopers (objects which are field galaxies, not dinamically bound to the primary, but are counted as satellites because of projection effects) is small. Interlopers must be equally distributed between prograde and retrograde, so their presence basically would "push" the prograde/retrograde ratio towards the value of 50%. We estimate this effect to be of the order of 2% for porcentages around 60% of prograde satellites.
Because we stack together systems of very different distances, we could have a problem as magnitude completeness cannot be fulfilled for all of them: some intrinsecally faint satellites would be observed in closeby systems, but not in distant systems. Through another Monte Carlo simulation, we are checking if this problem could have any effects on the prograde/retrograde ratio and the results are promising, in the sense that the ratio seems to be fairly insensitive to magnitude completeness and distance mixing. In a future paper we will address these questions in more detail.

REFERENCES

Afanasiev V.L. & Silchenko O.K. 1999, AJ 117, 1725A

McKay et al. 2002, ApJ, 571, L85

Prada F. et al. 2003, astro-ph/0301360

Stoughton C. et al. 2002, AJ 123,485-548

Zaritsky D., Smith R., Frenk C., White S.D.M. 1993, ApJ 405, 464-478

Zaritsky D., Smith R., Frenk C., White S.D.M. 1997, ApJ 478, 39-48

Complete sample statistics								
Displacement from Primary Major Axis	Prograde				Retrograde			
	N.	Mean dist. (kpc)	Mean vel. (km/s)	Vel. RMS (km/s)	N.	Mean dist. (kpc)	Mean vel. (km/s)	Vel. RMS (km/s)
−30° to +30°	11	138.2	69.9	45.9	8	118.9	68.6	40.9
−45° to +45°	20	125.2	83.7	75.6	14	156.6	117.4	119.2
−75° to +75°	30	186.9	70.8	66.4	18	151.7	117.3	106.9
−90° to +90°	36	200.1	86.0	89.8	28	210.9	135.5	123.7

Selected sample statistics (v < 7000 km/s)								
Displacement from Primary Major Axis	Prograde				Retrograde			
	N.	Mean dist. (kpc)	Mean vel. (km/s)	Vel. RMS (km/s)	N.	Mean dist. (kpc)	Mean vel. (km/s)	Vel. RMS (km/s)
−30° to +30°	4	157.2	26.0	15.3	5	166.4	49.8	40.4
−45° to +45°	10	140.3	85.1	98.8	7	177.4	137.5	153.9
−75° to +75°	17	191.4	66.8	81.5	10	155.2	127.5	131.5
−90° to +90°	21	207.7	85.2	105.6	15	196.3	116.6	119.0

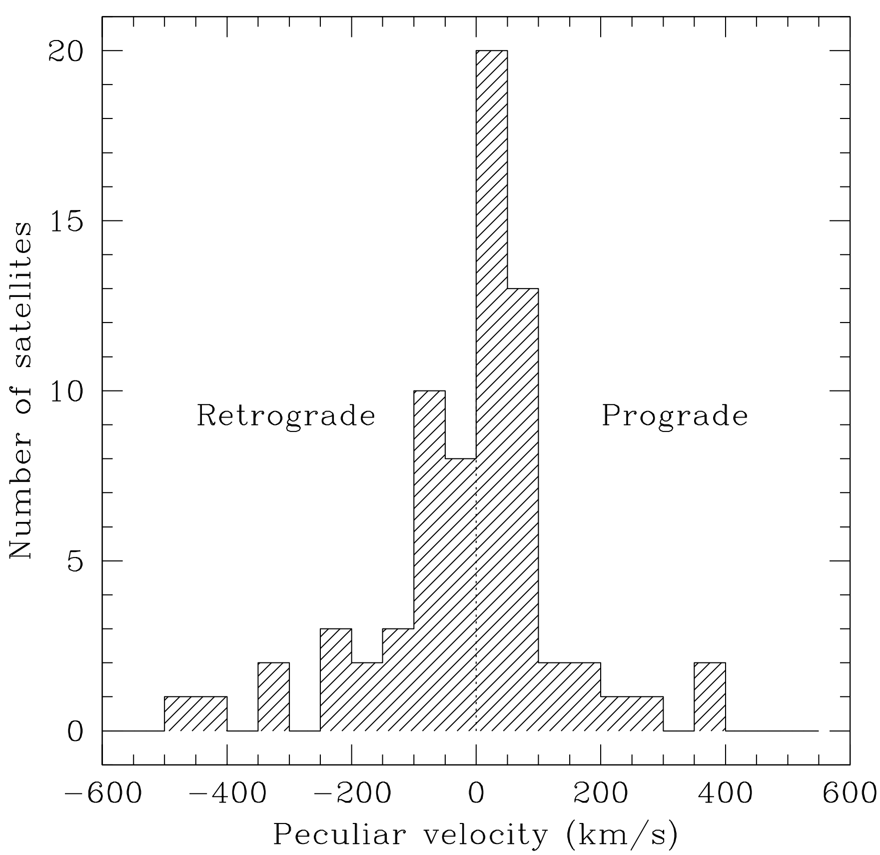

Fig. 1.— Statistics of the prograde and retrograde populations. The first panel shows our complete sample, the second panel only the primaries from our sample with recessional velocity below 7000 km/s like the Zaritsky sample. The bottom histogram shows the distribution